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Please find below and/or attached an Office communication concerning this application or proceeding.

PTO-90C (Rev. 10/03)

Office Action Summary	Application No.	Applicant(s)
	09/978,158	SAWHNEY ET AL.
	Examiner	Art Unit
	Kevin Siangchin	2623

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 1-27 is/are pending in the application.

4a) Of the above claim(s) 16-27 is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) 1-15 is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on 16 October 2001 is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date 10/16/01 ; 04/12/02.

4) ☒ Interview Summary (PTO-413) Paper No(s)/Mail Date. 111504 .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☐ Other: _____.

Detailed Action

Election/Restriction

1. Restriction to one of the following inventions is required under 35 U.S.C. § 121:

Invention I: Claims 1-11 and 12-15, drawn, respectively, to methods and apparatuses for creating a high-quality virtual image, as seen from a virtual viewpoint classified in Class 345, Subclass 955.

Invention II: Claims 16-21, drawn to methods for using and arranging a plurality of fixed imagers to create a mosaic, classified in Class 348, Subclass 42.

Invention III: Claims 22-24 and 25-27, drawn to methods for creating a local depth map of a scene, classified in Class 382, Subclass 154

2. Inventions I and Invention II and Invention III are related as subcombinations disclosed as usable together in a single combination. The subcombinations are distinct from each other if they are shown to be separately usable. In the instant case, Invention I has utility separate from that of Invention II such as creating a high-quality virtual image, as seen from a virtual viewpoint. The creation of such an image need not follow the methodology of Invention II, nor would it require a configuration of imagers such as in Invention II. In the instant case, Invention I has utility separate from that of Invention III such as creating a high-quality virtual image, as seen from a virtual viewpoint. The creation of such an image would not require depth images derived according to Invention III. In the instant case, Invention III has utility separate from that of Invention II such as creating a local depth map of a scene. The creation of such a local depth map can be achieved through imager arrangements other than those of Invention II. See MPEP § 806.05(d).

3. Because these inventions are distinct for the reasons given above and have acquired a separate status in the art as shown by their different classification, restriction for examination purposes as indicated is proper.

Election by Telephone

4. During a telephone conversation with Mr. Kenneth Nigon on November 15, 2004 a provisional election was made without traverse to prosecute Invention I – i.e. Claims 1-11 and 12-15. Affirmation of this election must be made by applicant in replying to this Office action. Claims 16-27 are withdrawn from further consideration by the examiner, 37 CFR § 1.142(b), as being drawn to a non-elected invention.

Specification

Objections

5. The disclosure is objected to because of the following informalities:

a. On page 21 of the Specification (paragraph [0102], second sentence), the word "reach" should be replaced with the word "reached".

b. Equation (3) on page 23 of the Specification is miswritten. It should be expressed as:

$$R_n(x,y,d) = \frac{1}{\max\limits_{(x',y',d') \in \Theta} S_n(x',y',d')}$$

6. Appropriate correction is required.

Claims

Objections

7. Claim 1 objected to because of the following informalities. To clarify the language of Claim 1, it is suggested that the limitations expressed in the phrase "scene covered by the plurality of fixed imagers" be removed from its place in the current claim language and placed instead in a less grammatically awkward position. The word "within" in line 2 of Claim 1 should also be changed to "of". For example the preamble could be rephrased as:

> In a system using a plurality of fixed imagers covering a scene, a method to create a high quality virtual image, in real-time, as seen from a virtual viewpoint of the scene, comprising …

Appropriate correction is required.

Rejections Under 35 U.S.C. § 102(b)

8. The following is a quotation of the appropriate paragraphs of 35 U.S.C. § 102 that form the basis for the rejections under this section made in this Office action:

> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

9. Claims 1-2, 5, 8-12, 15 are rejected under 35 U.S.C. § 102(b) as being anticipated by [ChenWilliams93] (S.E. Chen and L. Williams, *View Interpolation for Image Synthesis,* ACM-SIGGRAPH, 1993).

10. *The following is in regard to Claims 1 and 12.* [ChenWilliams93] is widely considered to be the seminal work in image-based rendering (IBR). [ChenWilliams93] introduces an approach for view synthesis based on the linear interpolation of corresponding image points using range (depth) data to obtain correspondences. Generally, the method assumes a plurality (at least two) viewpoints (which, in turn, may imply a plurality of corresponding imagers) of a given scene (e.g. [ChenWilliams93], page 281, left column, paragraph[1] 1). The presumption here is that, like most image-based rendering techniques, [ChenWilliams93] renders the interpolated scenes in real-time.

11. According to [ChenWilliams93], view interpolation (i.e. the creation of a virtual image – an image of the scene viewed from a virtual viewpoint) comprises the following steps:

(1.a.) The algorithm begins with at least two images of a scene (e.g. [ChenWilliams93], Section 2 *View Morphing*, paragraph 1, sentence 3). These can, of course, be captured by a set of corresponding "real" cameras.

(1.b.) At least two depth maps (range data of the images – e.g. [ChenWilliams93] page 280, left

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1 When referring to paragraphs in the cited references, the convention followed here is that the paragraph number is assigned to paragraphs of a given column (if applicable) or section, sequentially, beginning with the first full paragraph. Paragraphs that carry over to other columns will be referred to as the last paragraph of the column in which they began.

column, paragraph 1, lines 4-7) are generated using ranging devices, photogrammetric techniques ([ChenWilliams93] page 280, left column, paragraph 2, lines 4-6), or the like.

(1.c.)
1. The depth maps and viewpoint information are used to recover a dense set of correspondences between the pixels in each pair of images (e.g. [ChenWilliams93] page 280, left column, paragraph 1, lines 4-7).
2. These pair-wise pixel correspondences are used to determine a set of 3D spatial *offset vectors* ([ChenWilliams93], page 281, left column, paragraph 2, lines 4-18), which are then stored as a *morph map*[2].

The morph maps represent the forward mapping from one image to the other. However, because the map is generally many-to-one, a backward mapping must also be supplied in order to provide a complete representation of the pair-wise pixel correspondence. Thus, for each pair of images two morph maps must be provided ([ChenWilliams93], Section 2.1, *Establishing Pixel Correspondence*, paragraph 1, last two sentences). In other words, at least two sets of warp parameters (e.g. morph maps) are determined, each corresponding to one the input images. Again, the morph maps are determined using the depth maps (range data) associated with each of the given viewpoints (step (1.c.1) above).

12. [ChenWilliams93] further comprises the steps of:

(1.d.)
1. To generate a virtual view between a pair of images, the offset vectors of the morph map are interpolated linearly and the pixels in the source image are moved by the interpolated vector to their destinations (i.e. positions in the virtual image). See [ChenWilliams93] Section 2.2 *Interpolating Correspondences*, paragraph 1. This process yields an interpolated morph map[3].
2. [ChenWilliams93] forward map the source image using the interpolated morph map (e.g. [ChenWilliams93] Section 2.2 *Interpolating Correspondences*, paragraph 1 and

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2 Conceptually, the morph map is essentially the same as a disparity map ([ChenWilliams93], page 281, left column, paragraph 2, lines 10-15). It is well known in the field of computer vision that disparity is inversely proportional to the depth. Seen in this light, the morph map is also indicative of depth and can, therefore, be construed as a depth map. See [ChenWilliams93] Section 2.4.2, last paragraph, sentence 2.

3 The interpolated morph map forward maps the pixels of the source image to the interpolated image. It essentially approximates the perspective projection of the scene into the interpolated view.

[ChenWilliams93], Section 3.2 *Interactive Interpolation*, step 3), thereby, generating a warped or interpolated image representing the interpolated (virtual) viewpoint.

3. Each of the input images can act as both a source and destination image ([ChenWilliams93], Section 2 *View Morphing*, paragraph 2, lines 5-7). This process is repeated for each of the source images (ChenWilliams93], Section 2 *View Morphing*, paragraph 2, last sentence).

By repeating step (1.d.) for each of the source images, at least two warped (interpolated) images are obtained. Clearly, in the case of two input images, the first of these images is obtained according to the forward-mapping morph map and the second from the backward-mapping morph map (see step (1.c.) above)[4]. Again, these morph maps are considered here as warp parameters and are respectively associated with the given images.

13. For rendering purposes, the visibility of the warped pixels must be known. [ChenWilliams93] resolves visibility using a depth buffer (visible priority list – [ChenWilliams93] Section 2.4.2). Specifically, this comprise the steps of:

(1.e.)
1. Compositing multiple warped input images using their associated range information (depth maps), by organizing the pixels (or blocks of pixel) into a fixed visibility order ([ChenWilliams93] Section 2.3.1, Fig. 7 and Section 2.4.2, paragraph 3).
2. Once the visibility has been resolved for each pixel (and holes filled), the image corresponding to the virtual viewpoint can be properly rendered.

Essentially, the merging occurs in the depth buffer, with each depth layers being composited (or merged) in front-to-back order.

14. Image synthesis according to the teachings of [ChenWilliams93], therefore, comprises all substantive elements as set forth in Claim 1. The rejection of Claim 12 follows similarly.

4 Note that the designation of forward-mapping and backward-mapping is relative to which image is considered initially as the source. Clearly, this designation can be swapped.

15. *The following is in regard to Claim 2.* In [ChenWilliams93], as in most IBR techniques, the view of a virtual camera controlled by the user. See [ChenWilliams93] page 279, right column, lines 1-2.

16. *The following is in regard to Claim 5 and 15.* The range data (depth map) associated with each of the input images can be obtained according a variety of different techniques. One method suggested by [ChenWilliams93] is to obtain the range data using ranging sensors ([ChenWilliams93] page 280, left column, paragraph 2, lines 4-6). Though not explicitly disclosed in [ChenWilliams93], the following are clearly inherent aspects of such a configuration are clearly inherent:

(5.a.) Mounting the depth (ranging) sensors viewing the scene coincident with the fixed imagers. It is typically assumed that each pixel of an image is associated with a visible point in the three-dimensional space of a given scene. Each pixel is thus associated with a particular depth – the depth of the scene point. Generally, this depth is measured relative to the center-of-projection (COP) of the corresponding imager or viewpoint[5]. Therefore, if the aim is to generate range data from the COP of an imager to the viewed scene using depth sensors, then it is necessary that the depth sensors be mounted in close proximity (coincident, if feasible) to the location of the imager.

(5.b.) Selecting at least two depth sensors corresponding to the images.

(5.c.) Measuring a plurality of depth values (this is what depth sensor do!) with the depth sensors. As stated above, the depth values are required for each pixel (i.e. "the plurality of image coordinates") of the given images to determine the aforesaid pixel-to-pixel correspondences. See steps (1.b.)-(1.c.) above.

(5.d.) As stated above, a depth map (range data) is obtained for each of the input images. See steps (1.b.)-(1.c.) above. Clearly, in a configuration that utilizes depth sensors, these depth maps would consist of the measured depth values.

5 This, of course, assumes a pinhole camera model. This assumption is made by both the Applicant and [ChenWilliams93]. A pinhole camera is, for all intents and purposes, located at its center-of-projection.

It has thus been shown that an implementation of [ChenWilliams93], which utilizes ranging sensors to derive the range data of the given images, inherently comprises all substantive elements as set forth in Claim 5. The rejection of Claim 15 follows similarly.

17. *The following is in regard to Claims 8-11.* [ChenWilliams93] can synthesize novel views from images acquired at multiple viewpoints. [ChenWilliams93], therefore, supports multiple cameras (imagers). The authors pose no limit on the number of input images, other than there be at least two. Indeed, [ChenWilliams93] describes view interpolation primarily within the context of a two camera/two input image system (e.g. [ChenWilliams93], page 281, left column, paragraph 1) – that is, a system where exactly two images are selected. Also, a three camera system (a system where exactly three images are selected) is illustrated in Fig. 7 of [ChenWilliams93].

18. Assuming a three camera system (a system where exactly three images are selected), Fig. 7 of [ChenWilliams93] clearly shows exactly three images that correspond to three fixed imagers (e.g. View1, View2, and View3) arranged in a triangular fashion. This configuration is, of course, a geometric pattern of fixed imagers.

Rejections Under 35 U.S.C. § 103(a)

19. The following is a quotation of 35 U.S.C. § 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

20. Claim 3 is rejected under 35 U.S.C. § 103(a) as being unpatentable over [ChenWilliams93], in view of [Faugeras95] (O. Faugeras et al., *3-D Reconstruction of Urban Scenes from Sequences of Images*, INRIA, 1995).

21. *The following is in regard to Claim 3.* As shown above, [ChenWilliams93] satisfies all limitations of Claim 1. However, [ChenWilliams93] does not disclose selecting the virtual viewpoint based on tracking at least one feature in the scene.

22. [Faugeras95] discloses a method to reconstruct a three-dimensional model of a static environment viewed by one or several cameras whose motions or relative positions are unknown and whose intrinsic parameters are also unknown and may vary ([Faugeras95], Introduction, paragraph 1). The problem solved by [Faugeras95], though more in the realm of image-based modeling, is nonetheless similar to that of [ChenWilliams93]. [Faugeras95] suggests tracking a set of feature points through a given sequence of images. If a given feature point can be tracked all the way between two of the given views, a correspondence is established between those views. In this manner, a subset of the given set of images are used to establish feature correspondences between images. See [Faugeras95] Section 2 *Robust Recovery of the Geometry*, paragraph 1, sentence 1 and Section 2.1, paragraph 3, sentences 1-2.

23. Given the teachings of [Faugeras95], it would have been obvious to one of ordinary skill in the art, at the time of the Applicant's claimed invention, to select a subset of the given images in [ChenWilliams93] based on whether those images contain a set of tracked feature points. The advantages of such a modification are (at least) twofold. First, the resultant methodology would be capable of synthesizing novel views of designated feature(s) in the observed scene. Secondly, correspondences (and, presumably, all subsequent steps) are derived only for the reserved frames. As a result, the computational burden is reduced.

24. Claim 4 is rejected under 35 U.S.C. § 103(a) as being unpatentable over [ChenWilliams93], in view of [Trucco98] (E. Trucco and A. Verri, *Introductory Techniques for Computer Vision* © 1998, Prentice-Hall, Chapters 7-8) .

25. *The following is in regard to Claim 4.* As shown above, [ChenWilliams93] satisfies all limitations of Claim 1. [ChenWilliams93] further suggests determining the depth maps associated with each of the given images using photogrammetric techniques ([ChenWilliams93] page 280, left column, paragraph 2, lines 4-6). Although these techniques are well-known, [ChenWilliams93] does not propose using any particular photogrammetric technique.

26. Generally speaking, photogrammetry is the study in which the three-dimensional coordinates of points on an object are determined by measurements made in two or more photographic images taken from

different positions. The problem of stereo vision belongs to the field of photogrammetry. The essence of stereo vision lies in solving the *stereo correspondence problem* ([Trucco98] Section 7.1.1, paragraph 1).

27. As shown in [Trucco98] ([Trucco98] Section 7.1.1, paragraph 2, lines 1-6), the *disparity map* represents a solution of the stereo correspondence problem, assuming the geometry of the stereo system is known[6]. As stated previously, disparity is inversely proportional to depth. See also [Trucco98], page 144. The disparity map and depth map are, therefore, trivially related. Given the suggestion of [ChenWilliams93] to use photogrammetry to derive the depth maps, the teachings of [Trucco98] with regard to such a method, and the fact that [ChenWilliams93] presupposes *a priori* knowledge of the *intrinsic* and *extrinsic* camera parameters[3] ([Trucco98] page 144: *Parameters of a Stereo System*), it would have been obvious to one of ordinary skill in the art, at the time of the Applicant's claimed invention, to derive the depth (disparity) maps via stereo correspondence.

28. Under certain constraints, it can be shown that the *optical flow*[7] between a set of images and the disparity (hence, depth) are approximations of one another. To illustrate this, the notion of a *motion field* is introduced. The motion field is the two-dimensional vector field of velocities of the image points, induced by the relative motion between the viewing camera and the observed scene ([Trucco98], page 183). This relative motion may manifest itself as the viewing camera moving about a static scene. For static scenes, movement of the camera about the scene is equivalent to capturing the scene from a plurality of fixed cameras located at discrete locations along the path of the camera. The derivation of the motion field induced by a camera moving relative to a static scene is thus conceptually similar to the stereo correspondence problem for pairs of cameras fixed along the path of the moving camera. Indeed, the motion field coincides with the stereo disparity map when spatial and temporal differences between frames are sufficiently small ([Trucco98], page 185: *Stereo Disparity Map and Motion Field*). Returning to the discussion of optical flow, [Trucco98] points out that, if one assumes a globally illuminated scene of Lambertian (diffusive) surfaces, then optical flow is an approximation of the motion field ([Trucco98],

6 This is key assumption in [ChenWilliams93]. See [ChenWilliams93], Section 2.1, paragraph 1, sentence 3.

7 The optical flow is defined as the apparent motion of the image brightness pattern.

page 195: *Optical Flow and Motion Field*). Taking into account the previous observations, the following can be concluded. If a set of input images depicts a globally illuminated scene of Lambertian (diffusive) surfaces, from a corresponding set of tightly spaced and spatially coherent viewpoints, then the disparity map and optical flow field are approximations of one another[8,9]. These observations imply that, under the first and second constraints, the derivation of the disparity (depth) maps, using photogrammetric methods, involves:

(4.a.) Calculating a plurality of optical flow values (disparity) between the set of input images.

29. The disparity of an image pixel is actually the parallax[10] caused by viewing the corresponding scene point from different viewpoints. Disparity in image pairs is often referred to as binocular parallax. Thus, in calculating the disparity of an image pixel, one has also calculated a parallax value associated with the pixel. Given this observation, the derivation of the disparity (depth) maps further includes:

(4.b.) Calculating a plurality of parallax values (disparity) corresponding to pixels (i.e. a plurality of image coordinates) in the given input images from optical flow values (disparity).

30. [ChenWilliams93] satisfies both the first constraint ([ChenWilliams93] page 280, left column, paragraph 1, sentence 1) and the second constraint ([ChenWilliams93] page 280, right column, paragraph 1, lines 8-12). Therefore, the derivation of the depth maps implies steps (4.a.)-(4.b.) above and, thus, the step of:

(4.c.) Calculating the depth (disparity) maps using the image pixels and the parallax (disparity) values.

That is, steps (4.a.)-(4.c.) are implicit to the calculation of the depth maps by stereo reconstruction in the method of [ChenWilliams93].

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8 Note that the images are given and can be presumed to have been captured simultaneously. In this case, the temporal difference between images is negligible.

9 For the sake of brevity, the constraint of small spatial and temporal differences between frames will be referred to as the "first constraint"; and the "second constraint" will refer to the assumption of global illumination and Lambertian (diffusive) reflectivity for all scene surfaces.

10 Parallax is the apparent displacement or the difference in apparent location of an object as seen from two different viewpoints not on a straight line with the object.

31. Claim 7 is rejected under 35 U.S.C. § 103(a) as being unpatentable over [ChenWilliams93], in view of [Rogina01] (*U.S. Patent Application Publication 2001/0043737*, assigned to Rogina et al.).

32. *The following is in regard to Claim 7.* As shown above, [ChenWilliams93] satisfies all limitations of Claim 1. However, [ChenWilliams93] does not disclose selecting the input images based on a proximity of the virtual viewpoint to the viewpoints corresponding to the input images.

33. [Rogina01] discloses a method of providing an image from an arbitrary virtual viewpoint. In that method, a plurality of discrete two-dimensional images are acquired, each corresponding to the image of a scene observed from a plurality of discrete viewpoints on a predetermined viewpoint locus ([Rogina01] column 2, paragraph [0011], sentences 1-2; see also Fig. 1). In a process analogous to [ChenWilliams93], [Rogina01] uses an input viewpoint (base viewpoint) to map from transform images into the virtual viewpoint image ([Rogina01] column 2, paragraph [0011], last sentence). The base viewpoint is selected from the discrete viewpoint locus. According to [Rogina01], it is desirable to selected a base viewpoint close to the virtual viewpoint. See [Rogina01] column 2, paragraph [0011], sentences 5-6. Note that [Rogina01] also uses adjacent viewpoints in the view interpolation ([Rogina01], Abstract, lines 10-14). It that sense, the selection of the base viewpoint entails a selection of additional adjacent view points (which should also be close to the virtual viewpoint) – that is, at least two proximate images are selected.

34. It would have been obvious to one of ordinary skill in the art, at the time of the Applicant's claimed invention, incorporate this simple selection process into [ChenWilliams93]. According to [Rogina01], selecting the viewpoints closest to the virtual viewpoint alleviates skewing and accurately reflects occlusions of distant objects by close objects ([Rogina01] column 13, paragraph [0102]).

35. Claim 6 and 14 are rejected under 35 U.S.C. § 103(a) as being unpatentable over [ChenWilliams93], in view of [LuoMaître90] (W. Luo and H. Maître, *Using Surface Model to Correct and Fit Disparity Data in Stereo Vision*, IEEE, 1990).

36. *The following is in regard to Claim 6.* As shown above, [ChenWilliams93] satisfies all limitations of Claim 1. However, [ChenWilliams93] does not create the aforementioned depth (disparity) maps by:

(6.a.) Separating the given set of images into a plurality of segments, wherein pixels of each segment have substantially homogenous values.

(6.b.) Calculating a depth value corresponding to each segment.

(6.c.) Optimizing the depth values corresponding to each segment.

(6.d.) Creating the aforementioned depth maps from the plurality of optimized depth values

37. [LuoMaître90] disclose a method for stereo reconstruction[11] ([LuoMaître90] Abstract) comprising the steps of:

(6.a.) The images are segmented into regions of substantially uniform values (gray values). See [LuoMaître90] Section 3.1, item (b) and Abstract, sentence 3.

(6.b.) The depth value (disparity) of each segment is calculated. See [LuoMaître90] Section 3.1, item (a) and second to last paragraph, sentence 2.

(6.c.) The disparities of each segment (referred, henceforth, to as the disparity map of a segment) are optimized by the following:

1. Fitting a plane to the disparity map of each segment. See [LuoMaître90] Section 3.1, second to last paragraph, sentence 4.
2. The goodness-of-fit is determined. See [LuoMaître90], Section 3.1, last paragraph.
3. Errors are corrected ([LuoMaître90], Section 3.1, last paragraph, last sentence and Section 3.2).
4. If the fit is still unacceptable the segment is subdivided. See Section 3.3 of [LuoMaître90].

(6.d.) If the fitted planar model is acceptable for a given segment , it is fit to the measured disparity map. The fitted plane then becomes the "optimized" disparity map for the given segment. See [LuoMaître90] Section 3.4. This is clearly done for all segments in each of the input images so as to obtain a complete disparity (depth) map for each of the images.

11 Recall from above that stereo reconstruction yields a disparity or depth map associated with a given image.

38. The primary advantage of [LuoMaître90] is that fitted plane can provide a dense set of disparity values (depths) from a sparse set of measured disparities. Furthermore, as a mathematical model, the fitted plane has sub-pixel resolution. Taking this into account, it would have been obvious to one of ordinary skill in the art, at the time of the Applicant's claimed invention, to derive the depth (disparity) maps of [ChenWilliams93] according to the teachings of [LuoMaître90].

39. *The following is in regard to Claim 14.* As shown above, [ChenWilliams93] satisfies all limitations of Claim 12. As just discussed with respect to Claim 6, [LuoMaître90] is a segmentation-based method for disparity (depth) calculation. Note that the brightness value is never used in [LuoMaître90], aside from its use in evaluating the homogeneity of image regions. Therefore, it would have been obvious to one of ordinary skill in the art, at the time of the Applicant's claimed invention, to combine [LuoMaître90] and [ChenWilliams93], in the manner suggested above, and further extend [LuoMaître90] to accommodate color images.

40. Claim 13 is rejected under 35 U.S.C. § 103(a) as being unpatentable over [ChenWilliams93], in view of [Saito99] (H. Saito et al., *Appearance-Based Virtual View Generation of Temporally-Varying Events from Multi-Camera Images in the 3D Room*, IEEE, 1999).

41. *The following is in regard to Claim 13.* As shown above, [ChenWilliams93] satisfies all limitations of Claim 12. [ChenWilliams93], however, does not disclose using a view-based volumetric mapping means to create depth maps of the images.

42. [Saito99] proposes an "appearance [view]-based" virtual view generation method ([Saito99] Abstract). Depth images are derived for each camera using a multi-baseline stereo methodology ([Saito99] Section 4.1, paragraph 1). These depth images are merged to form a three-dimensional volumetric model ([Saito99] Section 4.1, paragraph 2). Using the volumetric model to resolve occlusions, [Saito99] derive a disparity (depth) map for each of the input views ([Saito99] Section 4.2 and Fig. 7). Clearly, in this sense, [Saito99] represents a view-based volumetric mapping means for creating depth (disparity) maps.

43. This volumetric process is superior because it successfully resolves occluded regions in all of the given views ([Saito99], Abstract, sentences 4-5). Therefore, it would have been obvious to one of ordinary

skill in the art, at the time of the Applicant's claimed invention, to use the method of [Saito99] to create depth images for each of the input images of [ChenWilliams93].

Citation of Relevant Prior Art

44. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure:

45. [Sawh3D94], [SawhSMM94], and [Kumar94] all relate recovery of the 3D geometry of an scene, observed at multiple viewpoints, using planar parallax. These may provide some theoretical insight into the Applicant's disclosed methods.

[Sawh3D94]	H. Sawhney, *3D Geometry from Planar Parallax.* IEEE, 1994.
[SawhSMM94]	H. Sawhney, *Simplifying Multiple Motion and Structure Analysis Using Planar Parallax and Image Warping*. IEEE, 1994.
[Kumar94]	R. Kumar, P. Anandan, and K. Hanna, *Shape Recovery from Multiple Views: A Parallax Based Approach.* Sarnoff Technical Report, 1994.

46. Various important IBR publications. Given the broadness of the current claim language, several of these methods "read on" the Applicant's claimed invention.

[LavFaug94]	S. Laveau and O. Faugeras, *3-D Scene Representation as a Collection of Images.* IEEE, 1994.
[SeitzDyer96]	S. Seitz and C. Dyer, *View Morphing.* ACM-SIGGRAPH, 1996.
[Gortler96]	S. Gortler et al., *The Lumigraph*. International Conference on Computer Graphics and Interactive Techniques: Proceedings of the 23rd annual conference on Computer graphics and interactive techniques, 1994.
[Shade98]	J. Shade et al. *Layered Depth Images.* ACM-SIGGRAPH 1998.
[McMillan95]	L. McMillan and G. Bishop, *Plenoptic Modeling: An Image Based Rendering*

System. ACM-SIGGRAPH, 1995.

47. [Mark97], like [Saito99] above, discloses several aspects of the Applicant's claimed invention, including the derivation of the depth maps for each input image and the warping and compositing of each input image to form a virtual image.

[Mark97]	W. Mark, L. McMillan, G. Bishop, *Post-Rendering 3D Warping.* ACM-SIGGRAPH, 1997.

48. The following are IBR methods for recovering depth and/or synthesizing new views. All involve some form of interpolation, warping, or morphing of the given images.

[Geogiev01]	T. Geogiev, *U.S. Patent 6,268,846.* Filing Date: June 1998.
[Sato02]	K. Sato, *U.S. Patent 6,445,815.* Filing Date: March 1999.
[Endo02]	T. Endo et al. *U.S. Patent Application Publication 2002/0171666.* Filing Date: August 1999.

49. Other "color-segmentation depth calculation means".

[Moravec99]	K. Moravec et al., *Using an Image Tree to Assist Stereo Matching.* IEEE, 1999.
[BlackJep96]	M. Black and A. Jepson, *Estimating Optical Flow in Segmented Images Using Variable-Order Parametric Models with Local Deformation.* IEEE, 1996.

50. Publications by the Inventors related to the claimed invention.

[TaoSawhGMC01]	H. Tao and H. Sawhney. *Global Matching Criterion and Color Segmentation Based Stereo.* Sarnoff Technical Paper, December 2000.
[SawhGuo01]	H. Sawhney et al. *Hybrid Stereo Camera: An IBR Approach for Synthesis of Very High Resolution Stereoscopic Image Sequences.* ACM-SIGGRAPH,

August 2001.

[TaoSawhGMM01] H. Tao, H. Sawhney and R. Kumar. *A Global Matching Framework.* IEEE, July 2001.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Kevin Siangchin whose telephone number is (703)305-7569. The examiner can normally be reached on 9:00am - 5:30pm, Monday - Friday.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Amelia Au can be reached on (703)308-6604. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

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